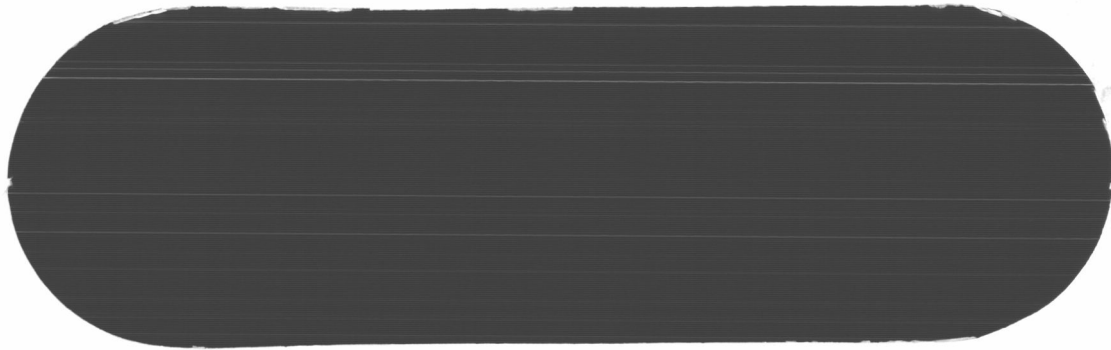


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TITLE METALLURGICAL ANALYSIS OF A 504 VEHICLE OXIDIZER TANK  
RING BAFFLE WEB, 60B12550-1 FAILURE

MODEL NO. Saturn V/S-IC CONTRACT NO. NAS8-5608

ISSUE NO. M-19 ISSUED TO R. L. Murphy

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#### ABSTRACT

The failure of an Oxidizer Tank Ring Baffle Web was reported in Unplanned Event Record U272347, July 15, 1967. Post static firing inspection of the 504 vehicle revealed the failure of a web in the first ring at position II of the lower bulkhead adjacent to the fill and drain port. Failure was attributed to the impingement of liquid oxygen; resulting in low and high cycle fatigue, initiating at minute stress corrosion cracks which were caused by rivet installation. The minute stress corrosion cracks found are localized conditions caused by rivet installation stresses. Normal usage will not cause the growth of these cracks by stress corrosion. Deflection of inflowing oxygen, greater control of liquid oxygen flow rate or the use of a heavier gage web should preclude the failure of ring baffle webs at this position.

#### KEY WORDS

Oxidizer Tank  
504 Vehicle  
Web  
7079-T6  
Fatigue  
Stress Corrosion

# TABLE OF CONTENTS

<u>REF. NO.</u>		<u>PAGE</u>
	Distribution	ii
	Change Record	iii
	Revisions	iv
	Abstract	v
	Table of Contents	vi
	List of Figures	vii
1.0	Object	1
2.0	Background	1
3.0	Conclusion	1
4.0	Recommendations	1
5.0	Procedures	1
6.0	References	3

# List of Figures

Figure No.		Page
1	Failed ring baffle web installed in oxidizer tank	4
2	Drawing 60B12550	5
3	Failed web as received in laboratory	6
4	Broken out segments	7
5	Fracture surfaces near primary origin	8
6	Opposite fracture surfaces at primary origin	9
7	Electron fractograph at primary failure origin	10
8	Electron fractograph at primary failure origin	11
9	Microstructure of web near the primary fracture origin	12
10	Microstructure of web near the secondary fracture origin	13
11	Microstructure of web near the tertiary fracture origin	14

1.0 OBJECT

The object of this study was to determine the cause of failure of a 504 Vehicle Oxidizer Tank Ring Baffle Web, 60B12550-1.

2.0 BACKGROUND

Post static firing inspection of the 504 vehicle revealed the failure of an Oxidizer Tank Ring Baffle Web, 60B12550-1. Unplanned Event Record U272347, July 15, 1967, reported a hole found in a ring baffle segment located in the first ring baffle at Position II of the lower bulkhead. Figure 1 shows four views of the installed web upon discovery of failure. It is noted that the failure occurred adjacent to the liquid oxygen fill and drain port. It appears that a portion of the entering liquid oxygen impinged upon the fractured web.

The failed web was made from 0.032 inch thick annealed 7079 aluminum alloy sheet, which was formed and then heat treated to the T6 temper. The drawing for 60B12550 is shown in figure 2. The web is installed in the Ring Baffle Segment Assembly, 60B12714-3.

3.0 CONCLUSIONS

It is concluded that the failure of an Oxidizer Tank Ring Baffle Web resulted from the impinging flow of liquid oxygen causing low and high cycle fatigue, initiating at minute stress corrosion cracks. The minute stress corrosion cracks were caused by rivet installation stresses resulting from the assembly of the Ring Baffle Segment.

4.0 RECOMMENDATIONS

It is recommended that either: (1) a heavier gage web be used in this location to resist the stresses caused by the filling of liquid oxygen and to compensate for the minute stress corrosion cracks which might exist near rivet locations; (2) inflowing liquid oxygen be deflected away from the ring baffle; or, (3) the liquid oxygen flow rate be controlled to produce low loading of the ring baffle.

5.0 PROCEDURES AND RESULTS

5.1 The failure of an Oxidizer Tank Ring Baffle Web was analyzed using optical and electron fractography, microscopy, hardness testing, tensile testing, conductivity testing, and chemical analysis.

Optical fractography was performed using a 7X-30X wide field stereoscope. Electron fractography was performed at 9,000X on a replicated surface. Fracture surface characteristics were examined to determine the type of failure and locate the initial point of failure. Microscopy of polished and etched specimens determined the fracture mode, and whether any irregularities existed in the microstructure of the material.

5.1 (Continued)

Chemical analysis was performed spectroscopically to determine conformance to alloy content. Hardness, conductivity, and tensile tests determined conformance to temper.

- 5.2 The failed part as received in the laboratory is shown in figure 3. The failure was such that two pieces were broken out from the web. The holes seen in both pieces are where samples for chemical analysis were removed. Figure 4 shows the convex and concave sides of these two pieces. The region marked is the major area of interest in fractographic analysis. The fracture surfaces were examined visually and under low magnification. The primary initiation point of failure is indicated in figures 3 and 4, by an arrow. However there are indications of fracture initiation at five locations. All initiation points are adjacent to rivet holes along the inboard edge of the web. None were through rivet holes, but at the contact point of the rivet head. Figure 5 shows four fractographs near the primary failure origin. Views A and D indicate that initiation was between these points, while the fracture pattern is characteristic of a tensile failure. Views B and C, directly adjacent to the initiation area, exhibit a fatigue type fracture pattern. Figure 6 shows the two opposite fracture faces at the primary origin, also exhibiting a fatigue mechanism. The combination of fatigue and tensile fractures observed in the fractographs indicates that failure resulted both from high cycle, low load fatigue and low cycle, high load fatigue mechanisms. Electron fractographs taken at the primary failure origin are shown in figures 7 and 8. The fracture mode was found to be intergranular, characteristic of stress corrosion cracking in aluminum alloy 7079-T6. The region of intergranular cracking observed is quite small, but could have acted as an initiation site for fatigue inception.

The results of microscopic examination revealed a normal microstructure for 7079-T6 aluminum alloy sheet. Cross section views near the first three origin points are shown in figures 9, 10 and 11. The failure mode is both transgranular and intergranular. The isolated areas of intergranular cracking confirm that stress corrosion cracking existed near rivet holes.

A spectroscopic chemical analysis revealed the material to conform to the requirements for aluminum alloy 7079. The average tensile strength of five specimens was 82 ksi., yield strength 71 ksi., and elongation 16 percent. These properties are above the minimums for the T6 temper. A conductivity of 34% IACS and hardness of Rockwell 82B were obtained, indicating a very slight overtempering. However the results of mechanical testing confirmed proper tempering.



5.3

In the course of fabrication, rivet installation in connecting the web to the segment assembly caused high localized sustained tensile stresses in the web. Atmospheric corrosion resulted in the formation of stress corrosion cracks. Upon crack initiation the rivet installation stresses were relieved, halting the further propagation of cracking due to stress corrosion. These minute cracks lay dormant until liquid oxygen impinged upon the web in the static firing filling operation. Vibration caused the propagation of these cracks slowly by high cycle fatigue, and then more rapidly by low cycle fatigue, aided slightly by the reduced notch strength of this alloy at lower temperatures. The formation of minute stress corrosion cracks appears to be a characteristic inherent in the fabrication of ring segments where sustained tensile stresses are caused by fit up. Improved fabrication techniques or the use of a heavier gage web in highly loaded areas should reduce crack formation and growth due to subsequent usage.

6.0

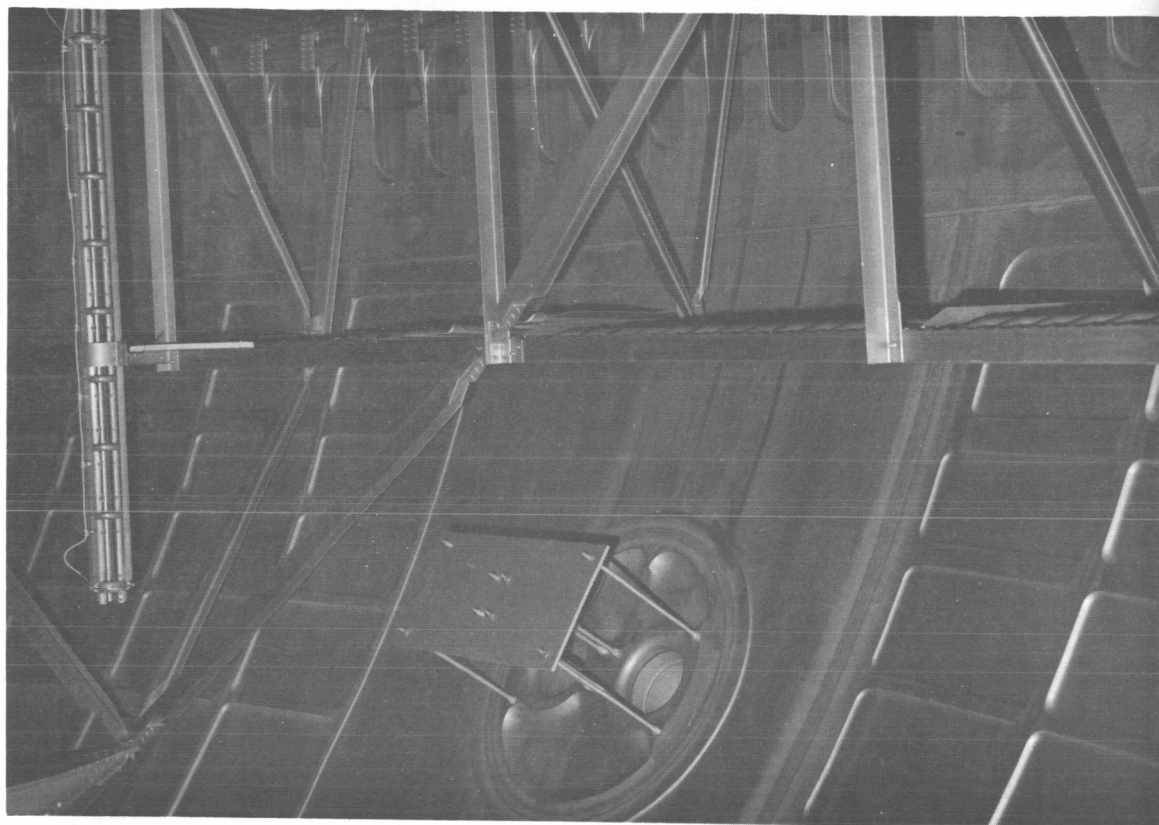
REFERENCES

Drawing 60B12550

Unplanned Event Record U272347, July 15, 1967

Coordination Sheet RU-2-370 E. C. Roberts to C.B. Schwartz,  
"Failure of Saturn Parts", August 11, 1967.

A



B

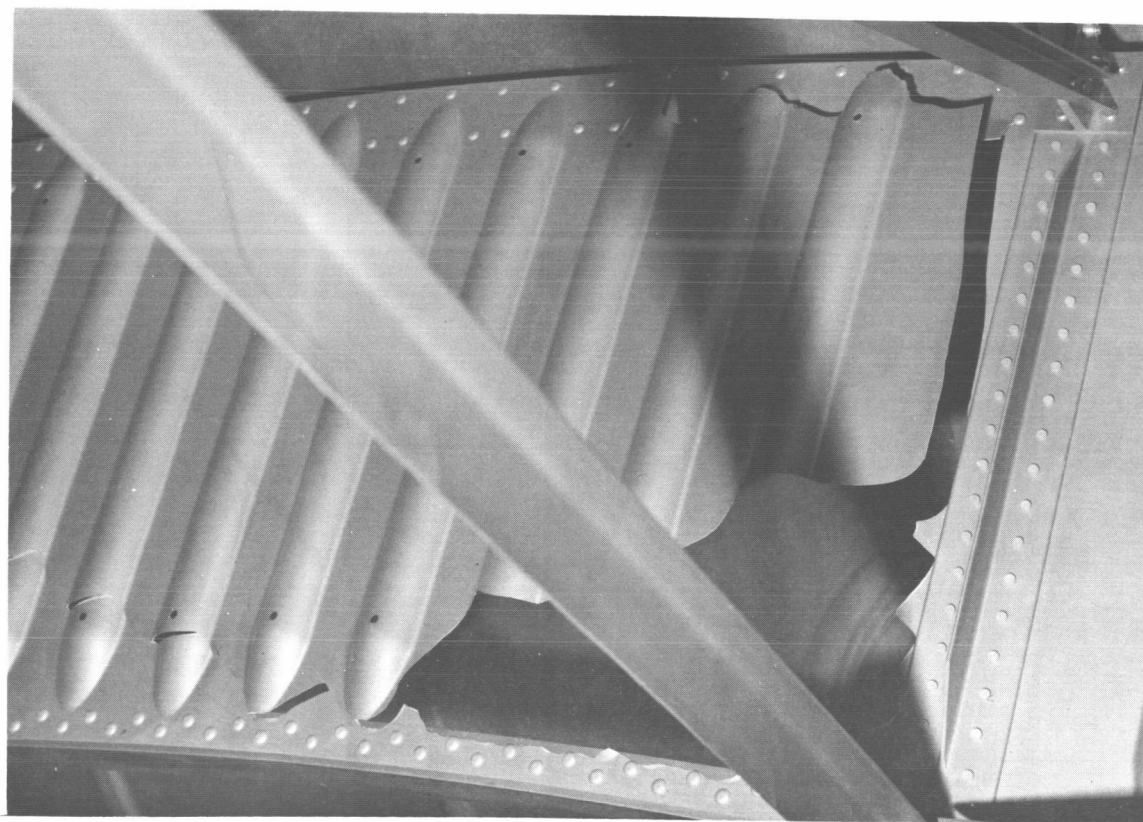
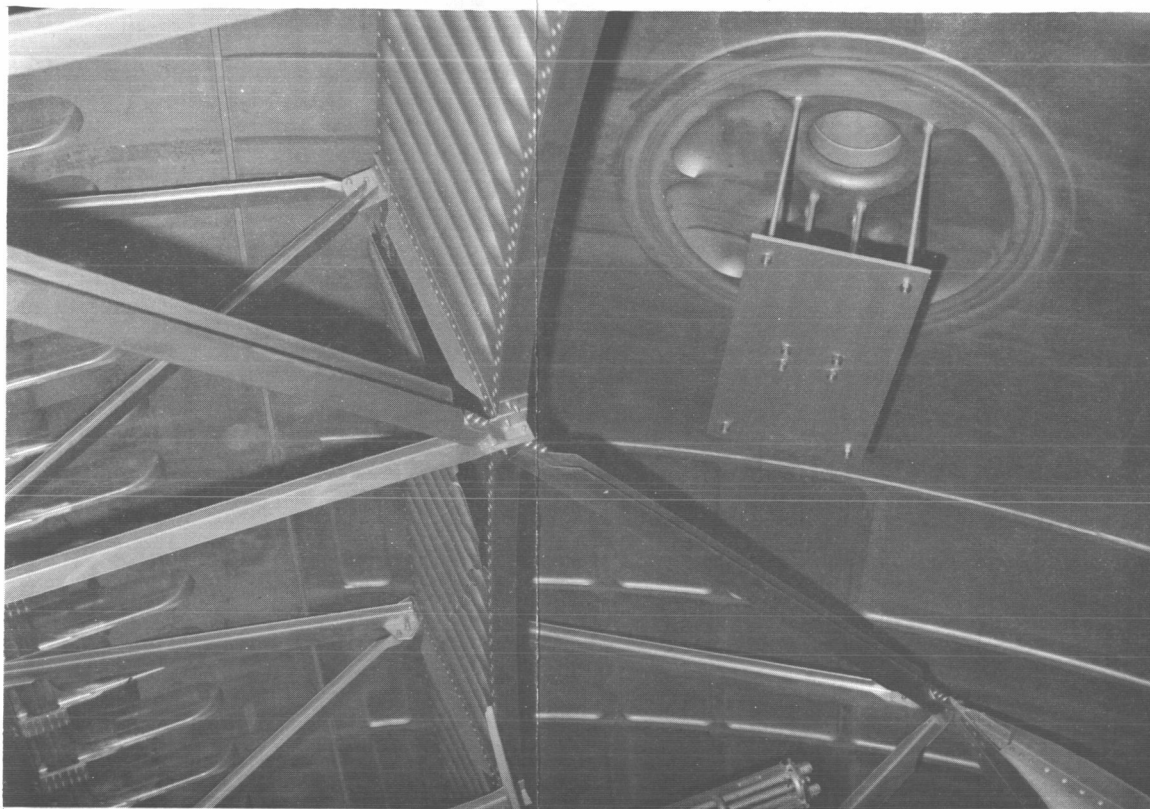


FIGURE 1 - FAILED RING BAFFLE WEB INSTALLED IN OXIDIZER TANK

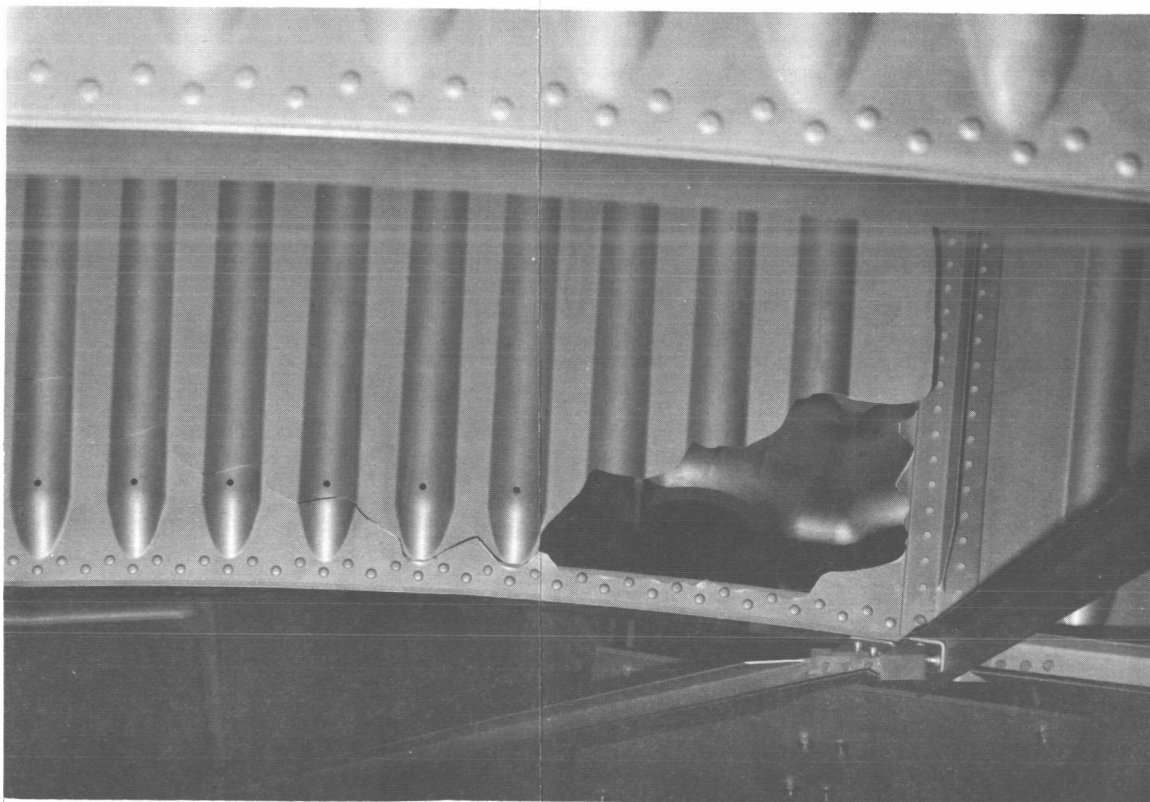
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FOLDOUT FRAME 1

C



D



60B12550

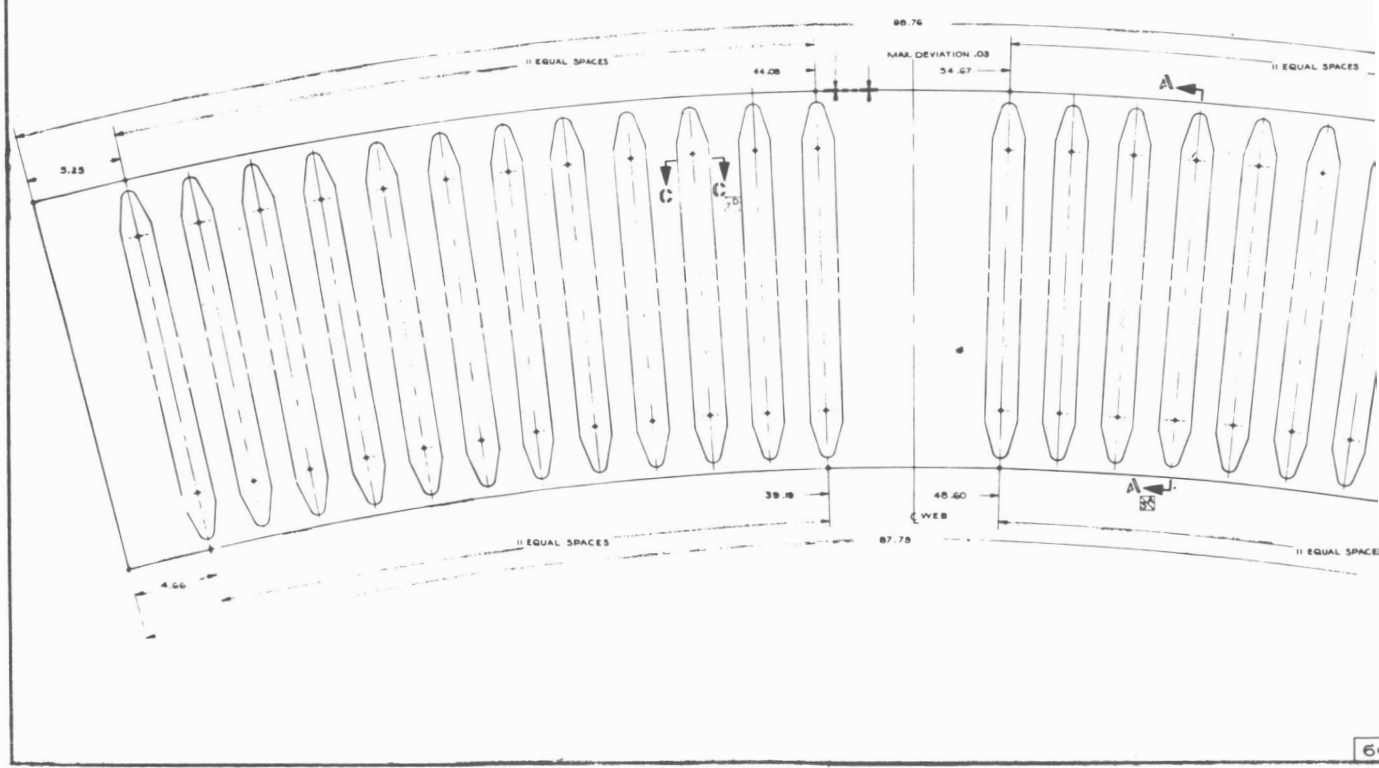
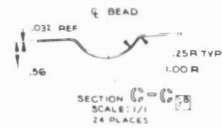
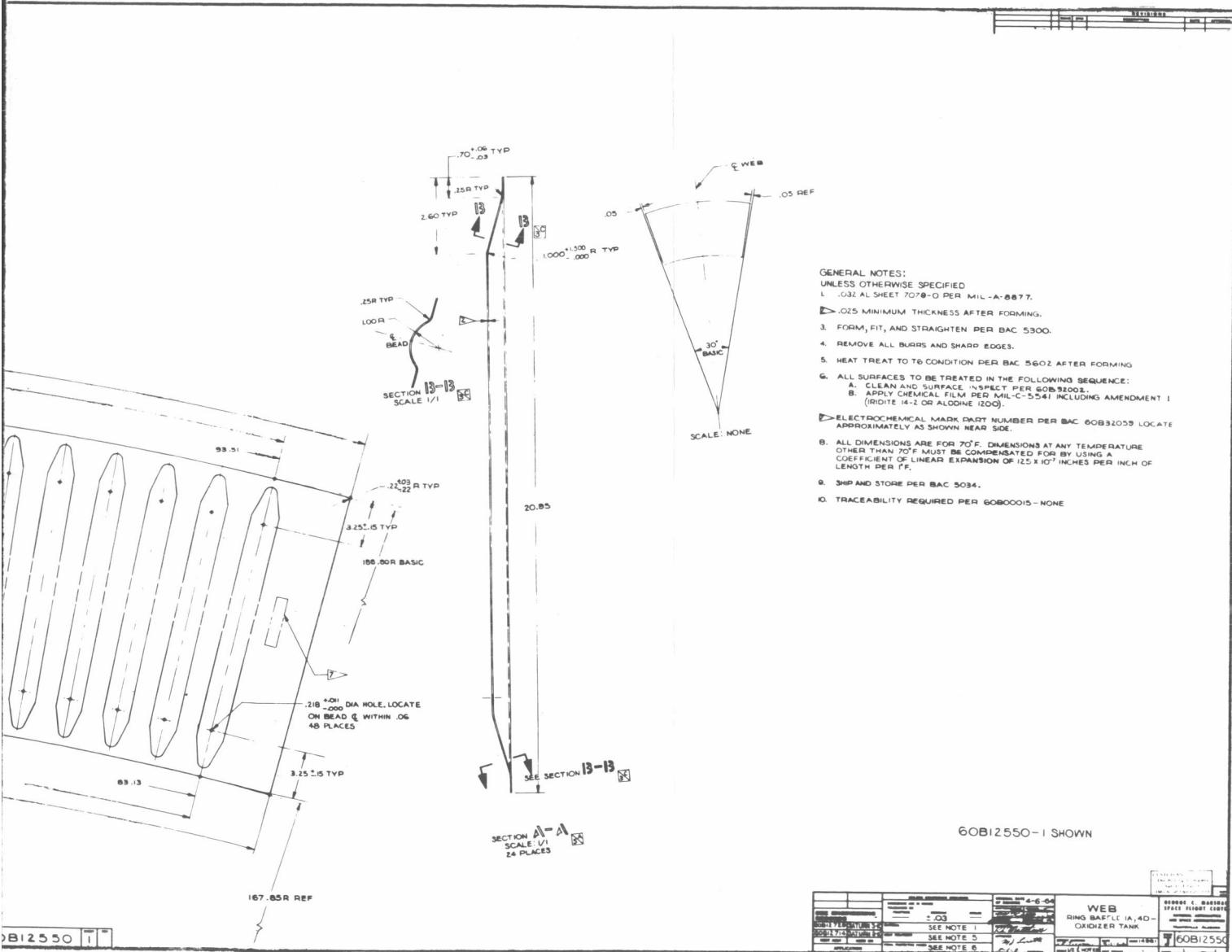


FIGURE 2 - DRAWING 60B12550

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FOLDOUT FRAME /



- GENERAL NOTES:  
UNLESS OTHERWISE SPECIFIED
1. .032 AL SHEET 7070-0 PER MIL-A-8877.
  2. .025 MINIMUM THICKNESS AFTER FORMING.
  3. FORM, FIT, AND STRAIGHTEN PER BAC 5300.
  4. REMOVE ALL BURRS AND SHARP EDGES.
  5. HEAT TREAT TO T6 CONDITION PER BAC 5602 AFTER FORMING.
  6. ALL SURFACES TO BE TREATED IN THE FOLLOWING SEQUENCE:
    - A. CLEAN AND SURFACE INSPECT PER 60B31002.
    - B. APPLY CHEMICAL FILM PER MIL-C-5541 INCLUDING AMENDMENT 1 (IRIDITE 14-2 OR ALDOLINE 1200).
  7. ELECTROCHEMICAL MARK PART NUMBER PER BAC 60B31009 LOCATE APPROXIMATELY AS SHOWN NEAR SIDE.
  8. ALL DIMENSIONS ARE FOR 70°F. DIMENSIONS AT ANY TEMPERATURE OTHER THAN 70°F MUST BE COMPENSATED FOR BY USING A COEFFICIENT OF LINEAR EXPANSION OF .025 X 10<sup>-3</sup> INCHES PER INCH OF LENGTH PER °F.
  9. SHIP AND STORE PER BAC 5034.
  10. TRACEABILITY REQUIRED PER 60B00015-NONE

60B12550-1		WEB		RING BASE (1A, 4D)		OXIDIZER TANK	
SEE NOTE 1		SEE NOTE 2		SEE NOTE 3		SEE NOTE 4	
SEE NOTE 5		SEE NOTE 6		SEE NOTE 7		SEE NOTE 8	
SEE NOTE 9		SEE NOTE 10		SEE NOTE 11		SEE NOTE 12	



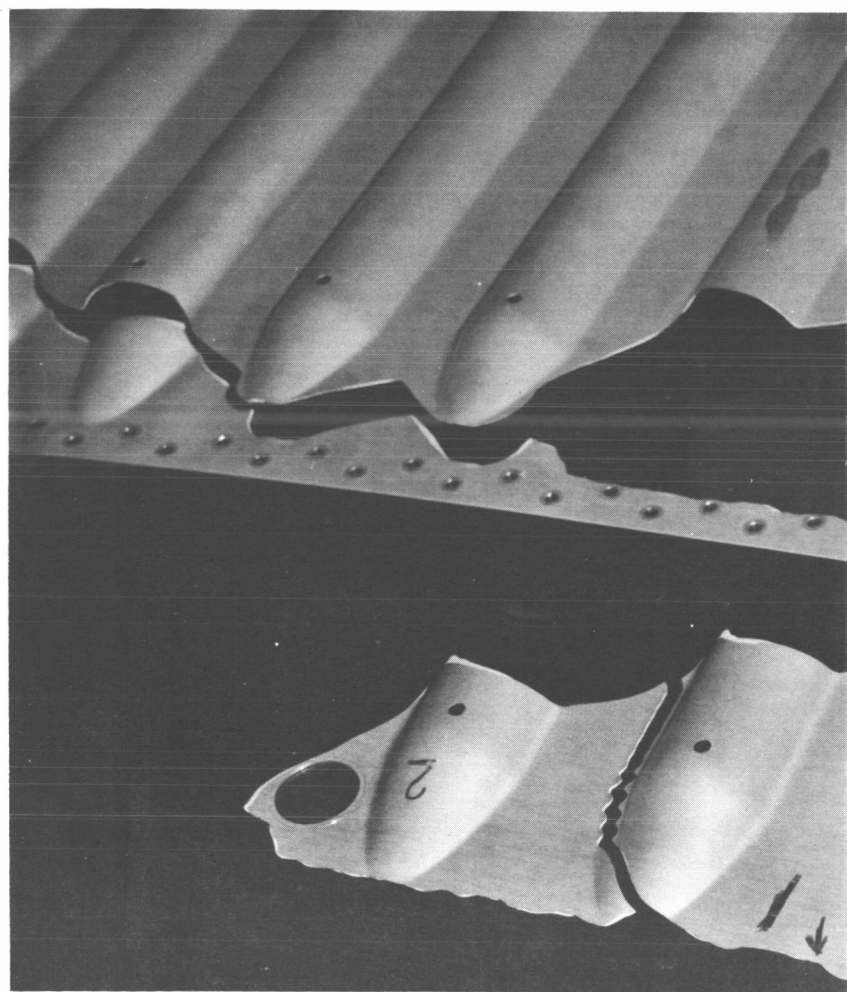
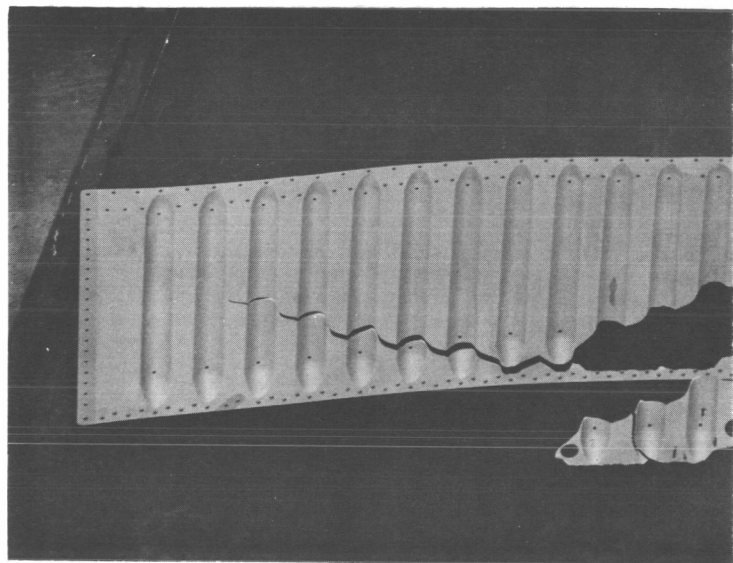
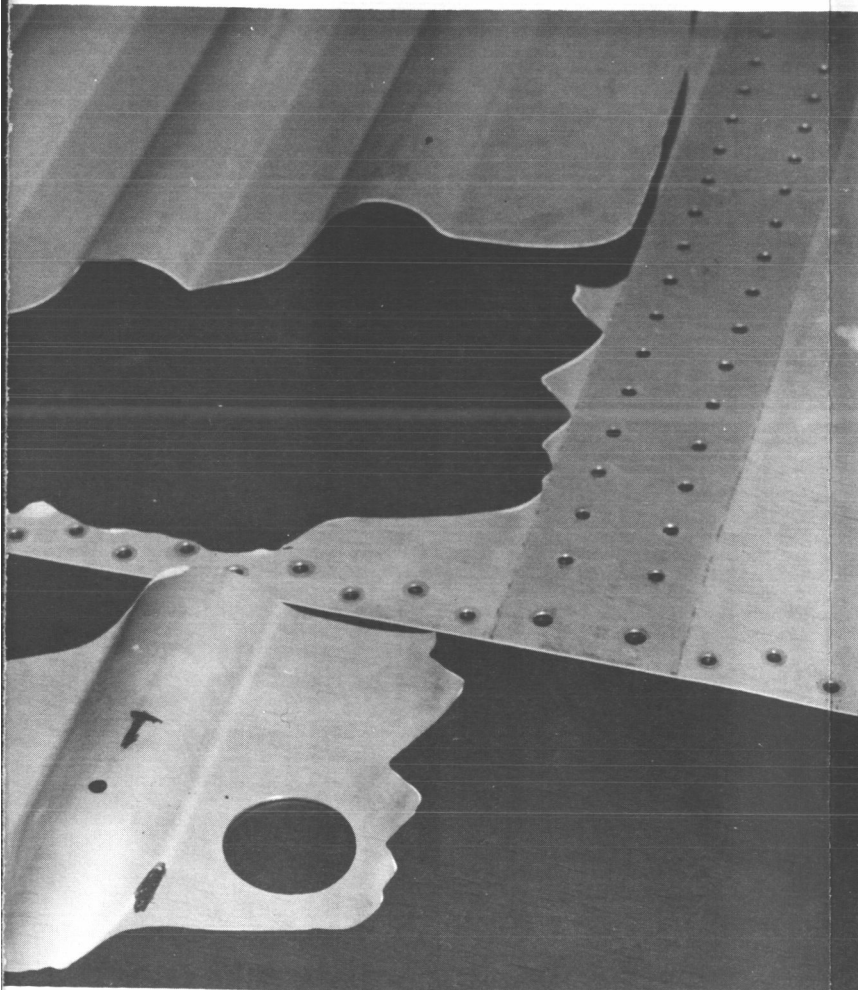
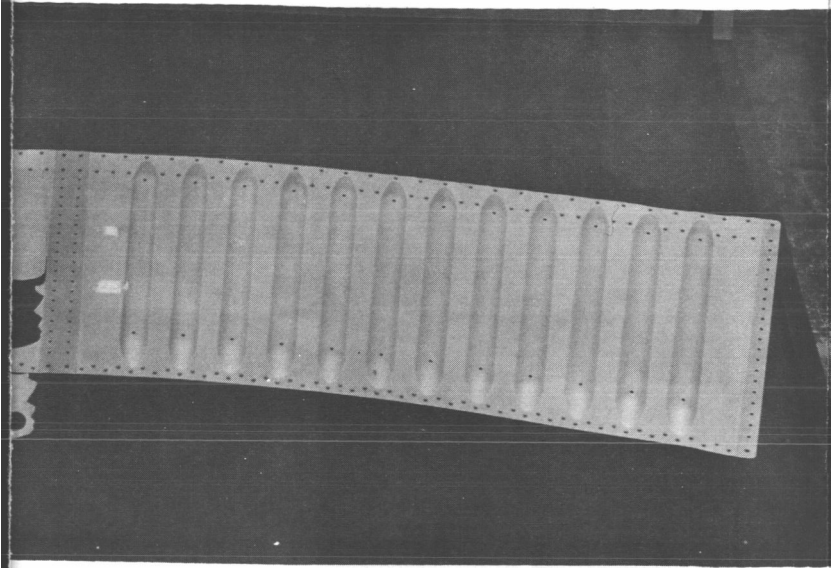


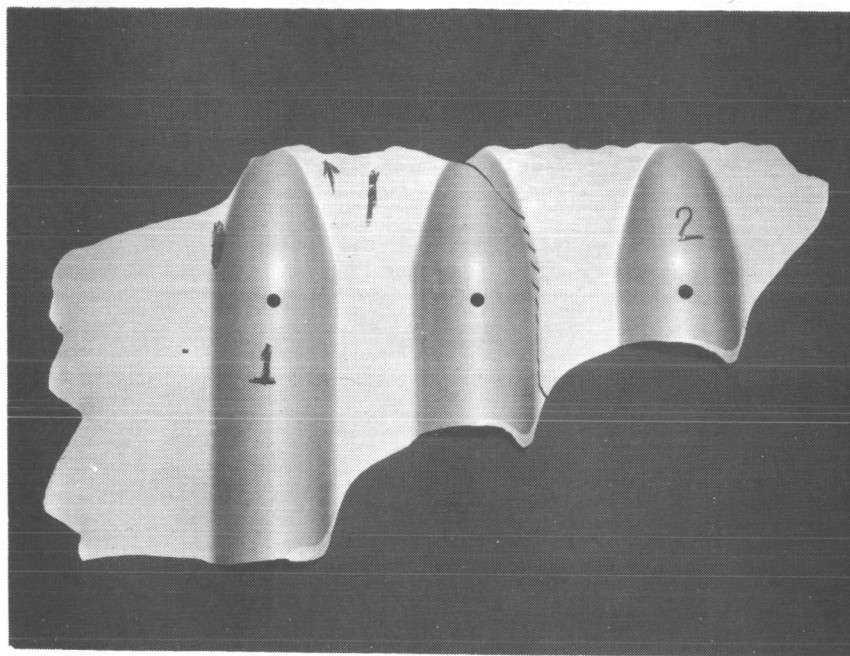
FIGURE 3 - FAILED WEB AS RECEIVED IN LABORATORY

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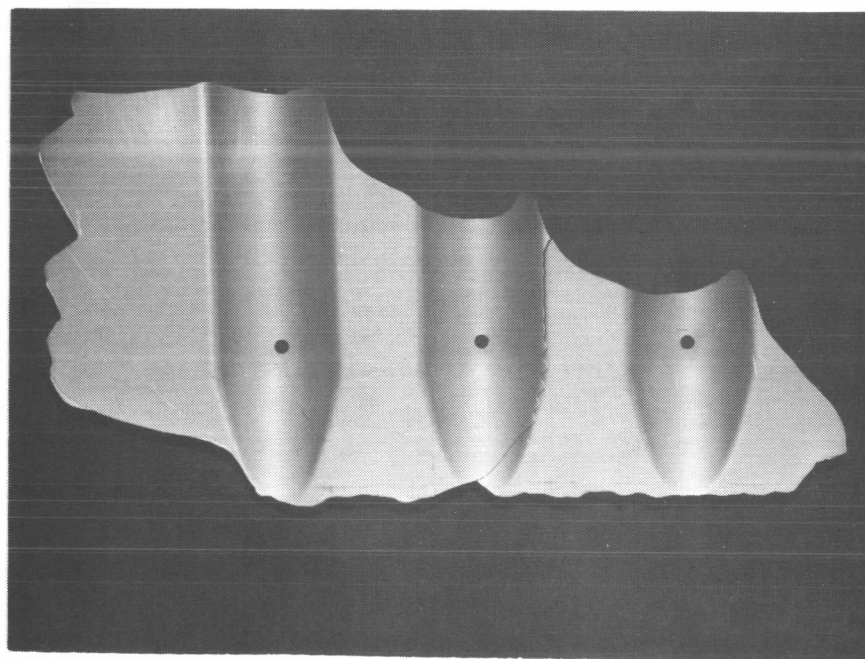
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Note: Material removed from  
sections 1 and 2 for  
chemical analysis





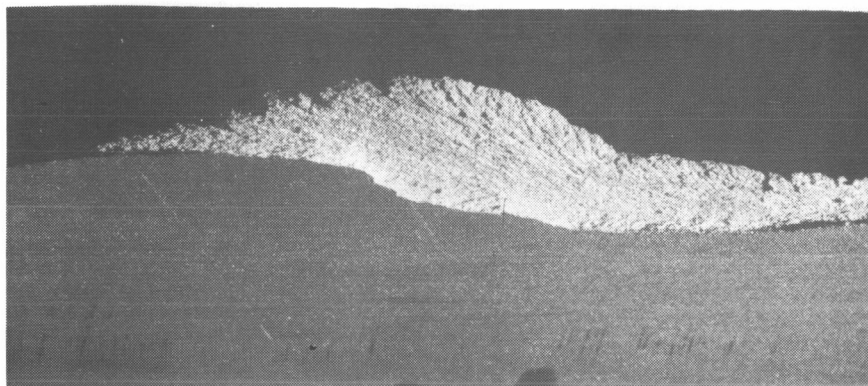
A - Convex surface, 1/3X



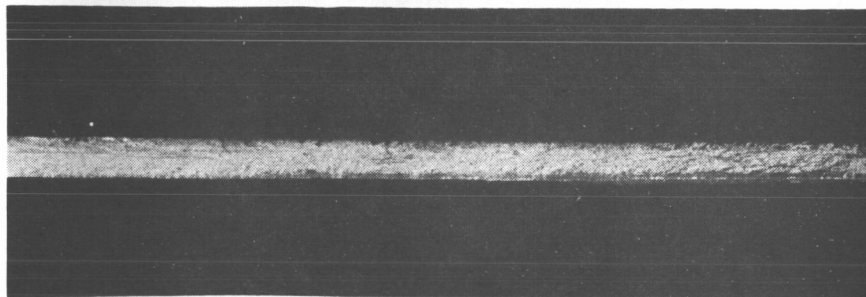
B - Concave Surface, 1/3X

Figure 4 - Broken Out Segments

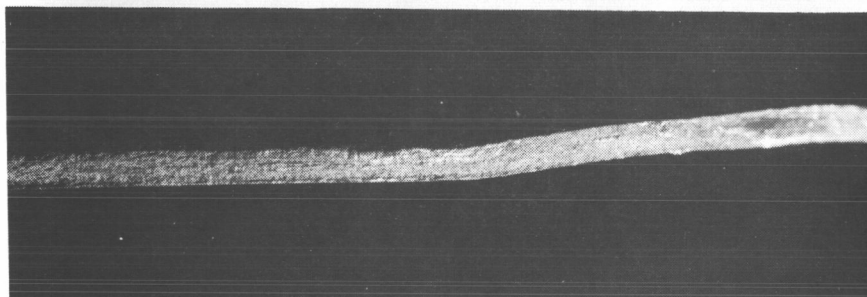




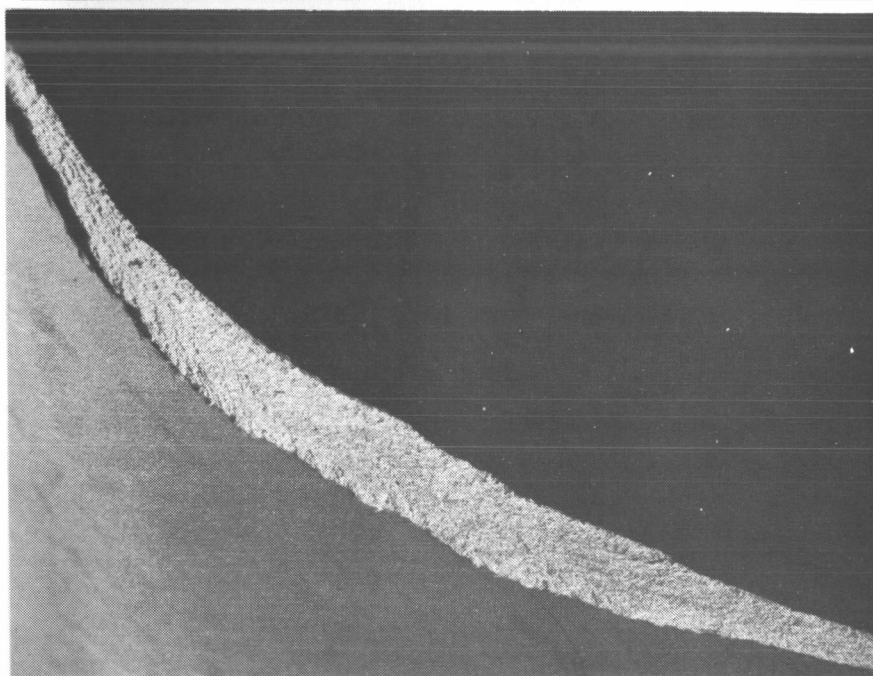
A



B

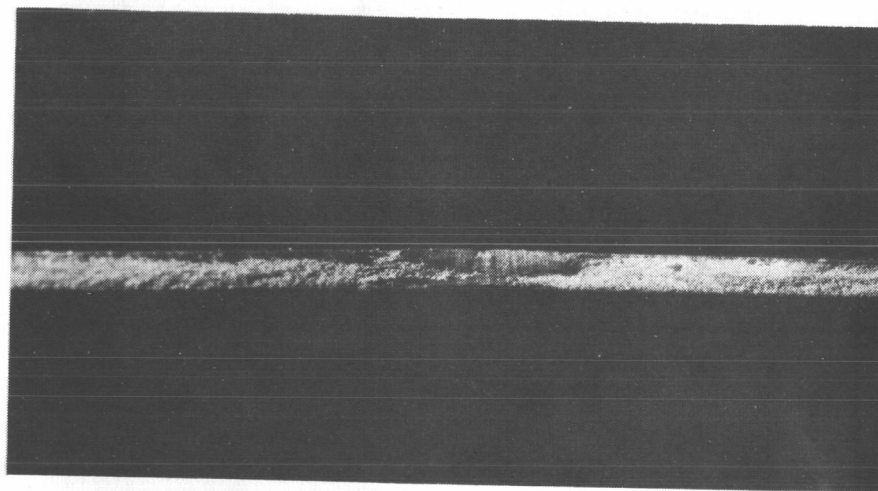


C

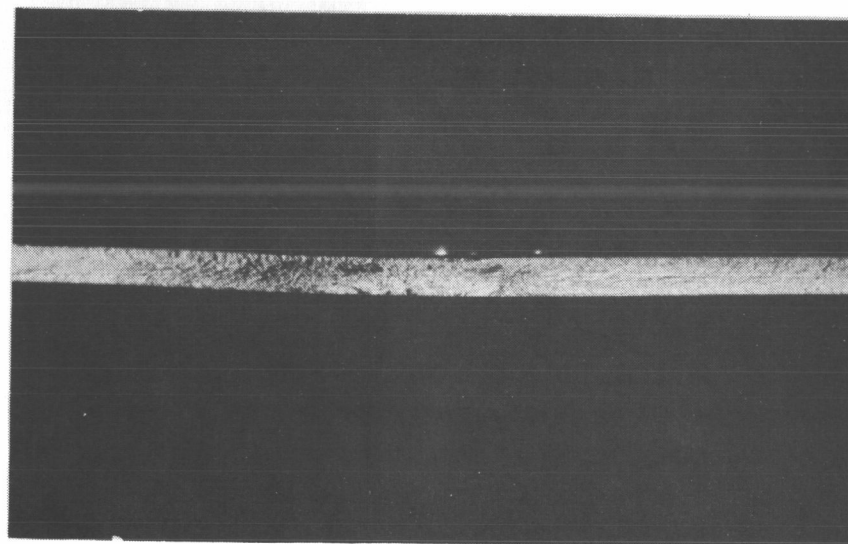


D

Figure 5 - Fracture Surfaces Near Primary Origin, 6X



A



B

Figure 6 - Opposite Fracture Surfaces at Primary Origin, 6X

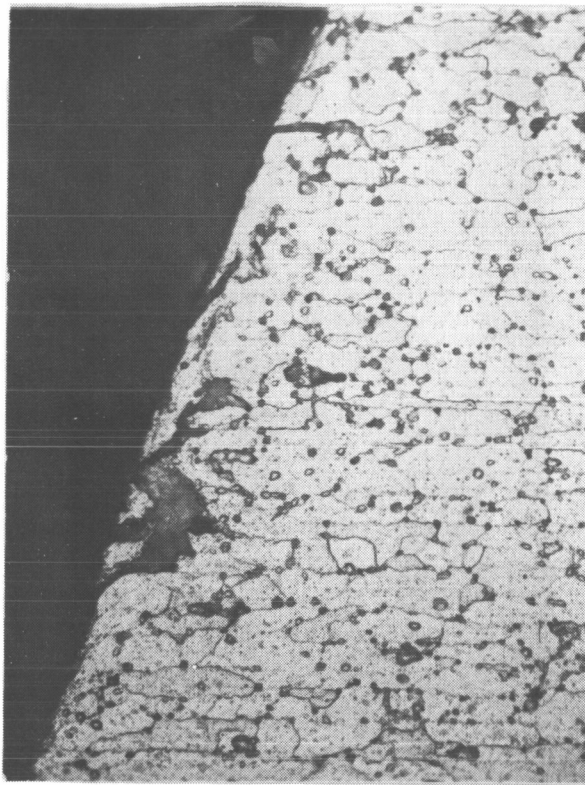


Figure 7 - Electron Fractograph at Primary Failure Origin, 9,000X

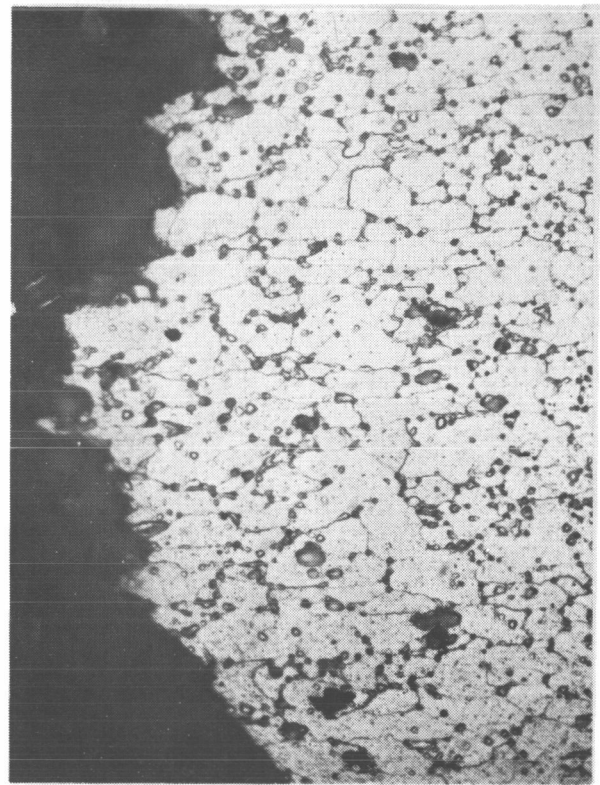




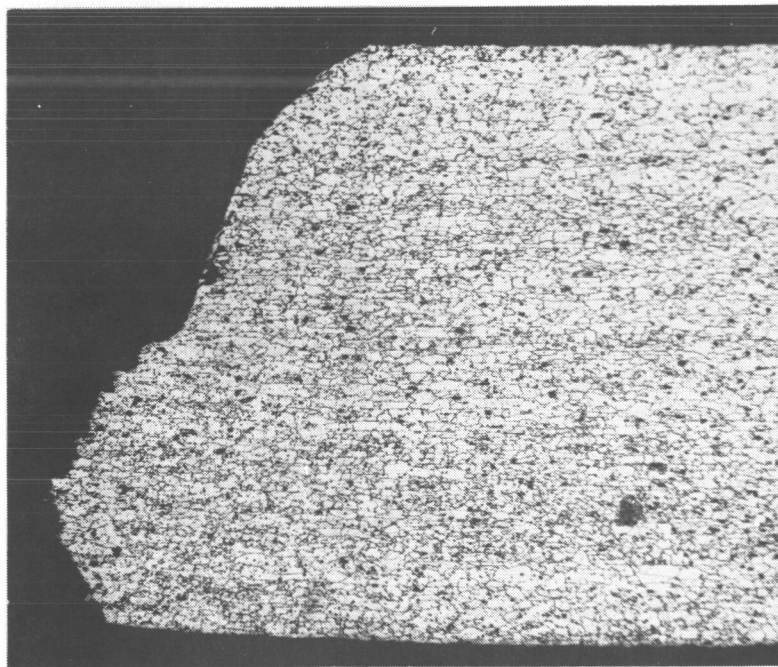
Figure 8 - Electron Fractograph at Primary Failure Origin, 9,000X



B-500X

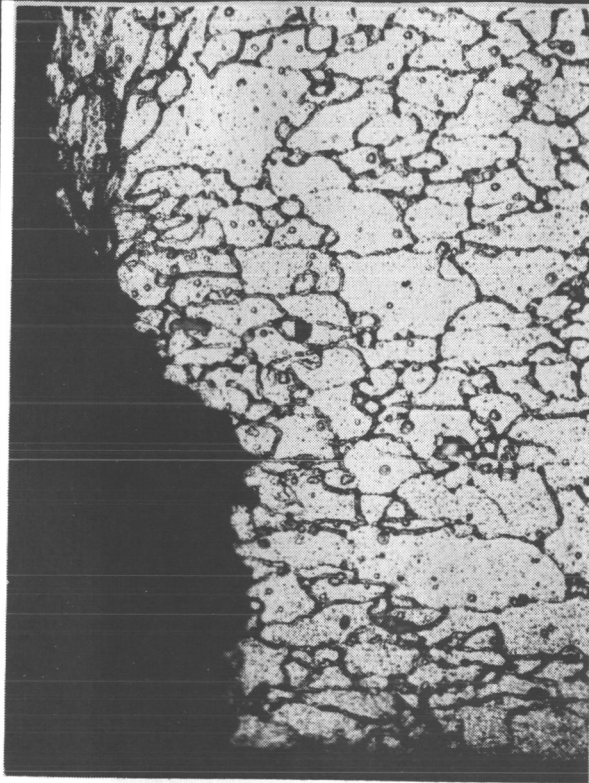


C-500X

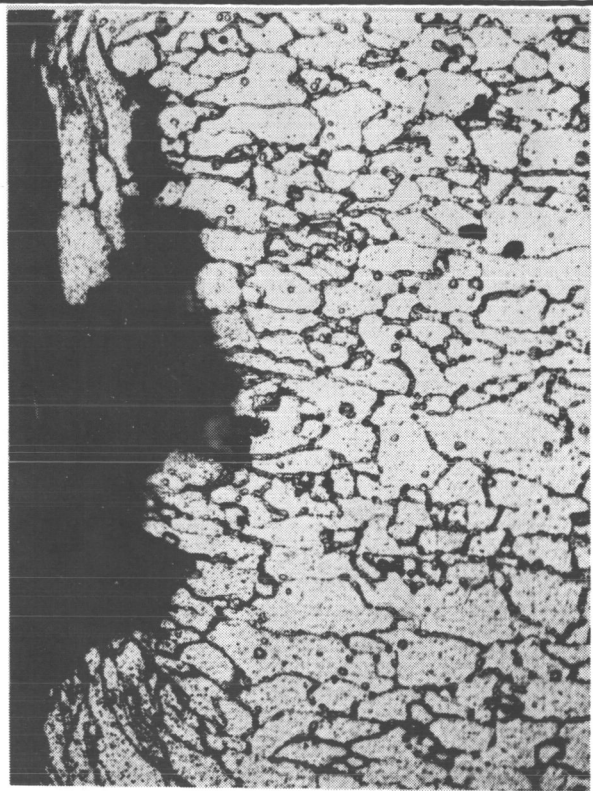


A-100X

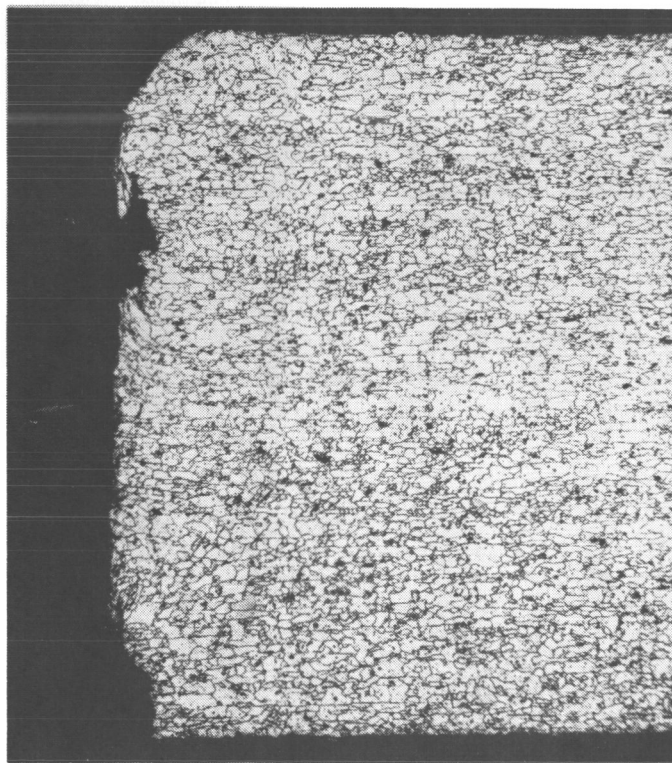
Figure 9 - Microstructure of web near the primary fracture origin. Keller's Etch



B-500X



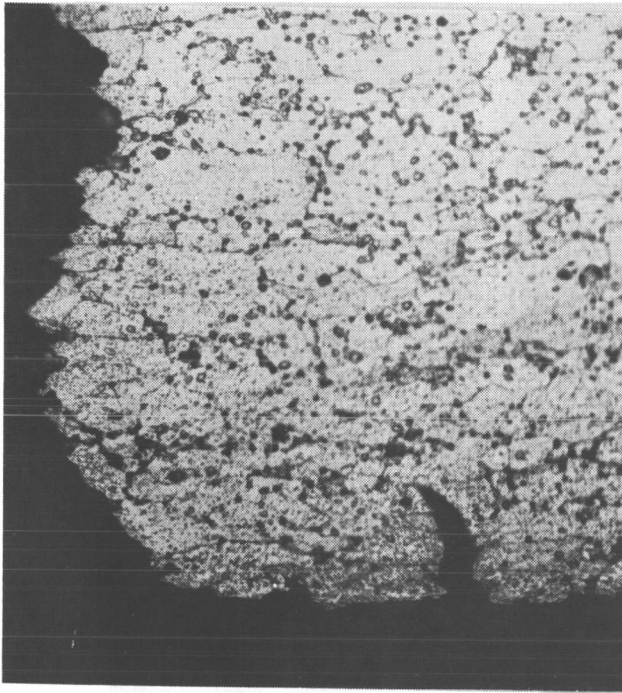
C-500X



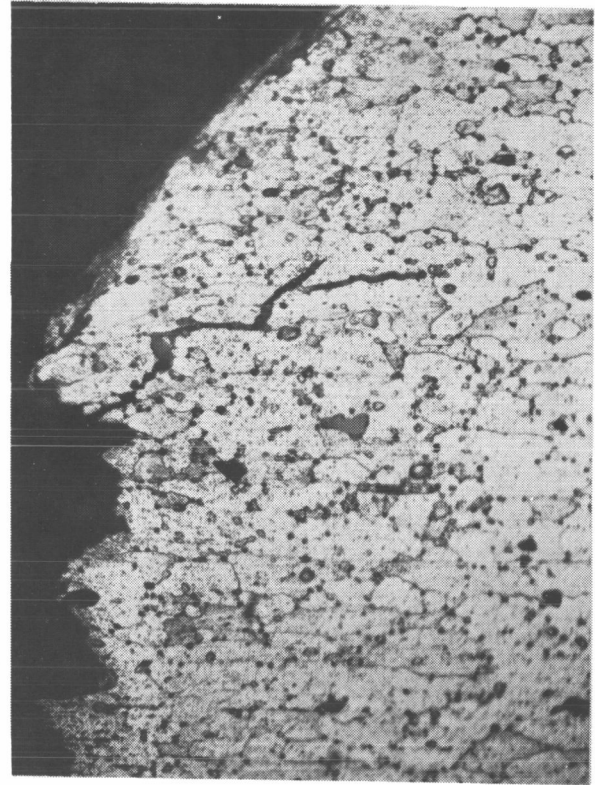
A-100X

Figure 10 - Microstructure of Web Near the Secondary Fracture Origin, Keller's Etch

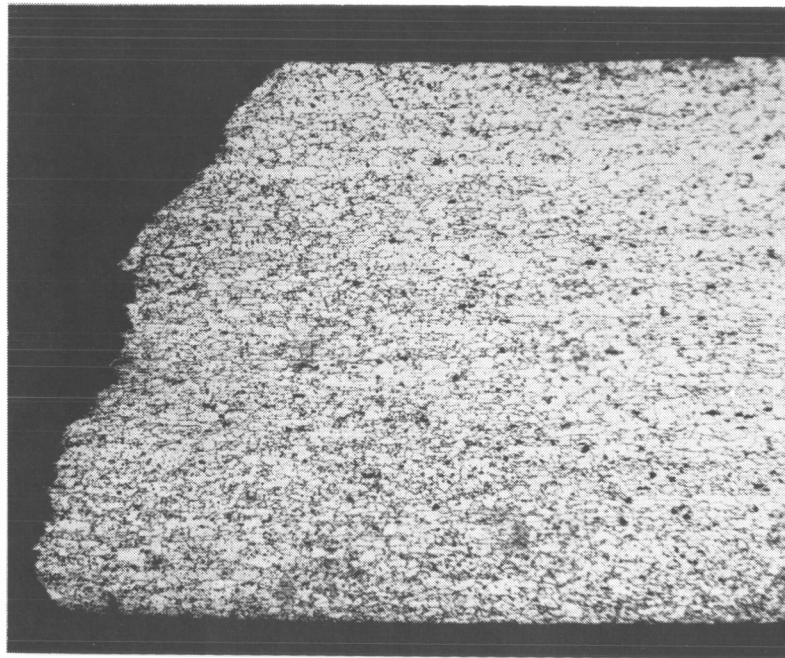




B-500X



C-500X



A-100X

Figure 11 - Microstructure of Web Near the Tertiary Fracture Origin, Keller's Etch